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Abstract

ADVANCES IN NEUTRON-ACTIVATION ANALYSIS

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Great strides have been made in neutron-activation analysis since 1958. Many of the major advances in technique and applications are described in this paper.

Major improvements have been made in all three types of neutron sources used for neutron-activation-analysis work: isotopic, accelerator, and nuclear reactor sources. The older isotopic sources have now been augmented by americium-beryllium sources, and the availability of californium spontaneous fission sources is expected in the near future. These are, of course, low-flux neutron sources. Many improvements have been made in the low-cost deuteron accelerators which produce 14-MeV neutrons by means of the H-3(d,n)He-4 reaction, and such accelerators are now widely used in science and industry for medium-flux (10^7 - 10^9 n/cm^2 .sec) thermal-and fast-neutron-activation analysis. Some of these recent improvements include the use of vac-ion pumps, target refrigeration, high tritium-content targets, large rotating targets, target replenishment by means of H-3 bombardment, and magnetic deflection of D_2^+ ions. Major developments in research reactors used for neutron-activation analysis include the extensive utilization of reactors with a large-capacity, uniform-flux rotating sample rack, and of reactor pulses.

New developments in neutron-activation techniques include (1) systematic use of the high fluxes of fission-spectrum fast neutrons present in the reactor, (2) the employment of high-intensity (10^{16} - 10^{17} n/cm^2 .sec) reactor pulses for enhancement of detection sensitivities for very short-lived induced activities, (3) the utilization of delayed neutrons in the activation detection of fissionable species, and (4) the development of very rapid post-irradiation

radiochemical separation techniques, now successfully employed with induced activities having half lives as short as a few minutes.

Along with the recent advances in techniques and capabilities, and the wider appreciation of the power of the method, the application of neutron-activation analysis has greatly increased and has spread to many fields of science, industry, and medicine. The method, employing small deuteron accelerators, is now in wide use especially in the petroleum and chemical industries, for routine medium-sensitivity elemental analysis. The method has especially found a high degree of application in the field of rapid oxygen determinations, via the O-16(n,p)N-16 reaction, at levels down to about 5 parts/million of oxygen. Some of the many improvements recently made in this technique include (1) use of a dual pneumatic transfer system (for sample and standard), (2) several excellent flux-monitoring systems, (3) rotation of sample during irradiation, (4) corrections for neutron scattering and gamma-ray scattering in the sample, and (5) development of very low oxygen-content sample containers. The chemical industry has also pioneered interesting applications of pesticide-residue determinations, determination of catalyst residues in polymers, and in the activation-analysis detection of stable isotopes, such as N-15 and O-18, used in tracer studies. The coal industry has carried out interesting activation-analysis studies of the continuous determination of ash constituents in coal.

In geochemistry, important studies are being carried on in the determination of rare-earth element abundances in meteorites, in calcium isotope ratios, and in Rb-Sr age dating. With its tremendous sensitivity, the method, employing the high neutron fluxes available in nuclear reactors, is naturally finding more and more use in ultra-pure materials such as the alkali metals, Be, C, Al, Si, Ti, Fe, Ge, Zr, Nb, and Pb. A very interesting new field of application is that of scientific crime detection, in which several important advances have already been made. In the field of space exploration, a completely automatic, miniaturized neutron-activation analysis system has been developed for analysis of the surface of the moon.